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(54) **AUTO BEAM OPTIMIZATION FOR PHASED ARRAY WELD INSPECTION**

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CPC *G01N 29/04* (2013.01); *B23K 31/125* (2013.01); *G01N 29/2487* (2013.01); *G01N 29/262* (2013.01); *G01N 2291/056* (2013.01); *G01N 2291/106* (2013.01); *G01N 2291/2675* (2013.01)

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(57)   **ABSTRACT**

A method of computing optimal beam numbers of a phased-array ultrasonic weld inspection arrangement. The arrangement is for inspecting a weld that is within an area of interest that has a known dimension and with the inspection arrangement being at a known offset distance from the weld. The selection is such that operation of the at least one element provides sufficient information data for weld analysis. The elements extend along an ultrasonic transmission wedge of the arrangement that supports the extent of the elements at a wedge angle relative to the welded material. The method includes utilizing the dimension of the weld area of interest and dimension of offset of the inspection arrangement from the weld within calculation that yields the selection of the at least one element.

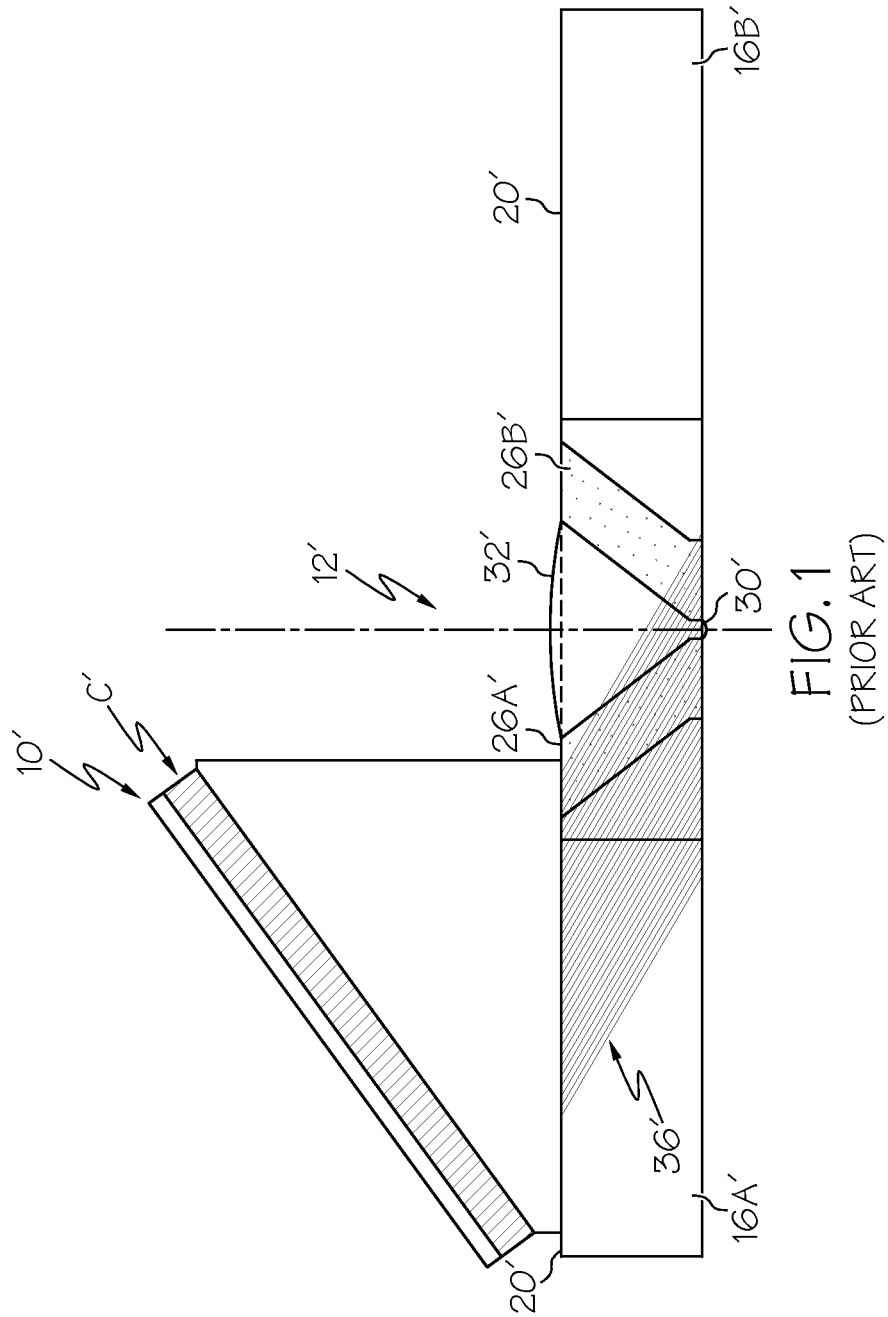**10 Claims, 7 Drawing Sheets**
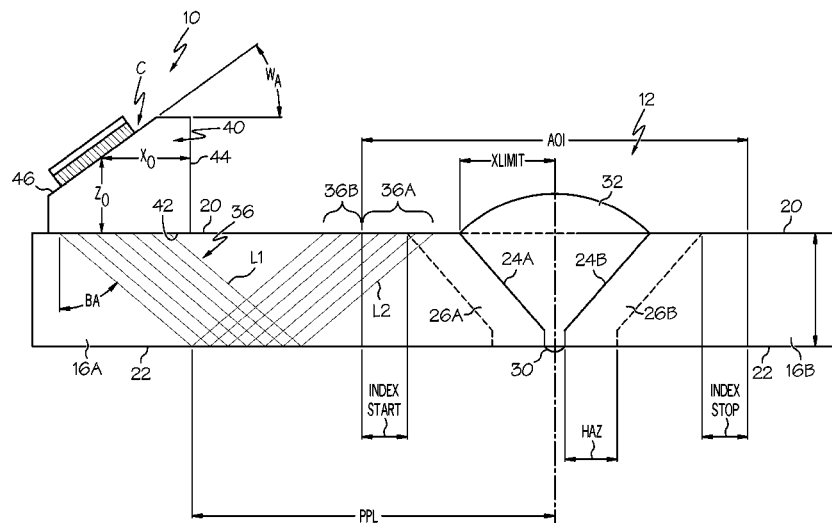
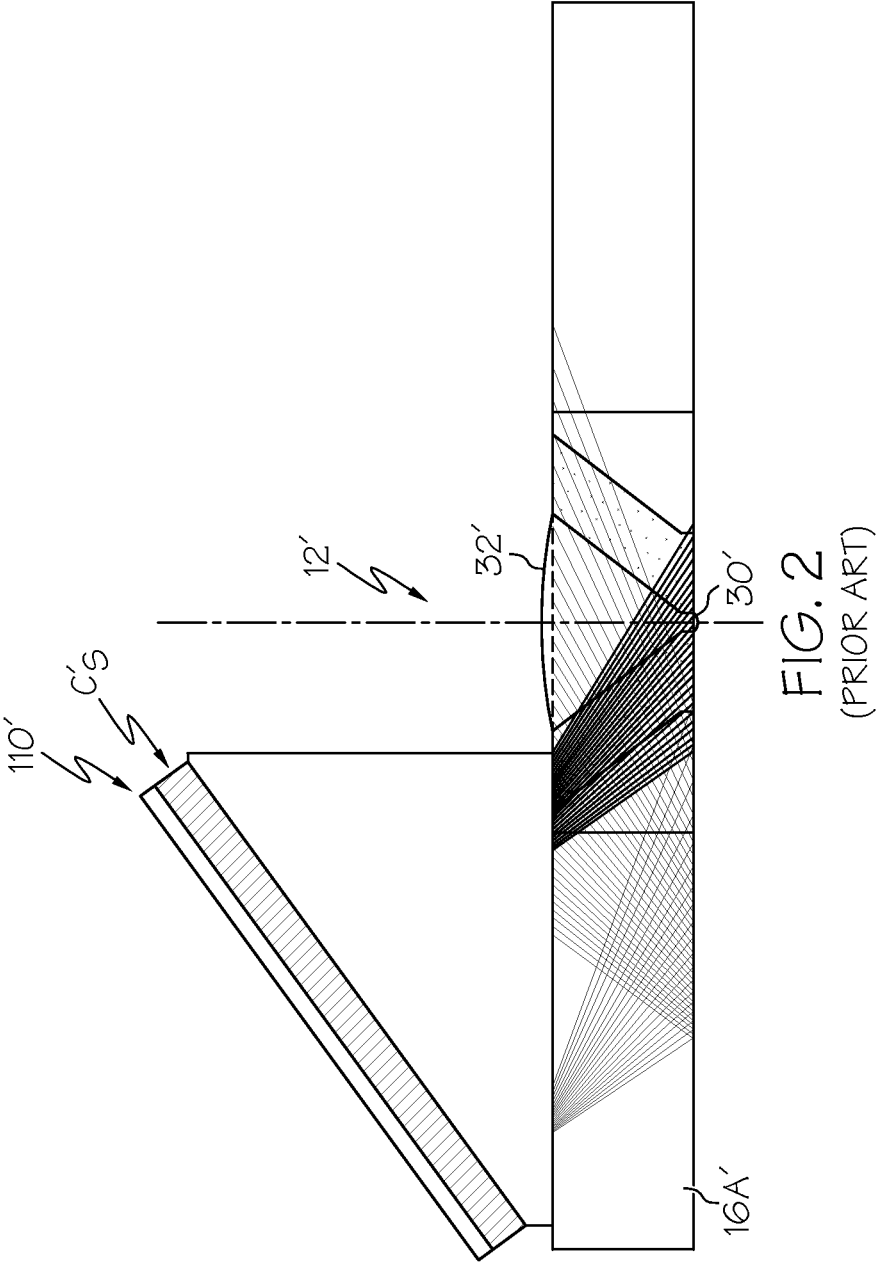(56)   **References Cited**

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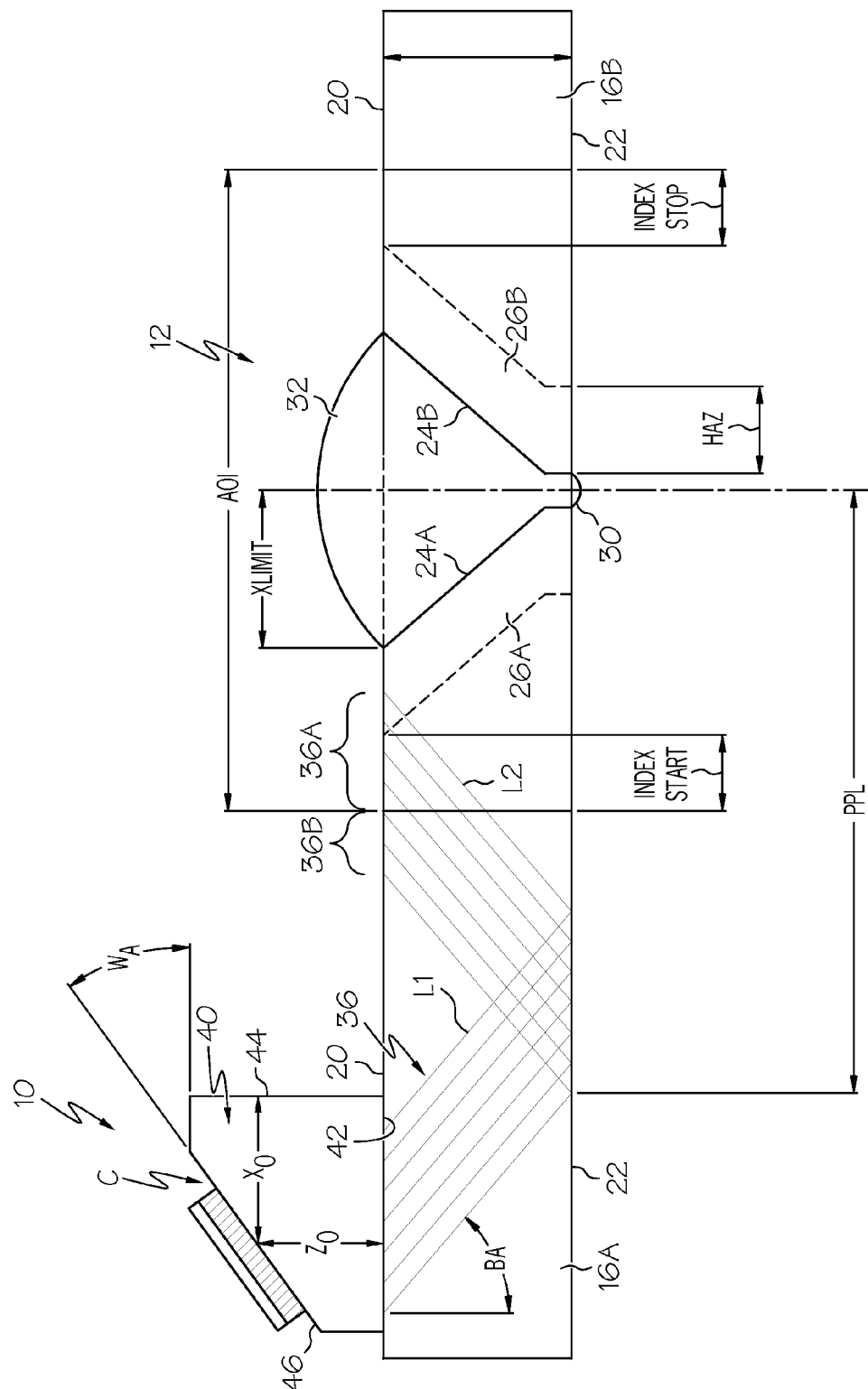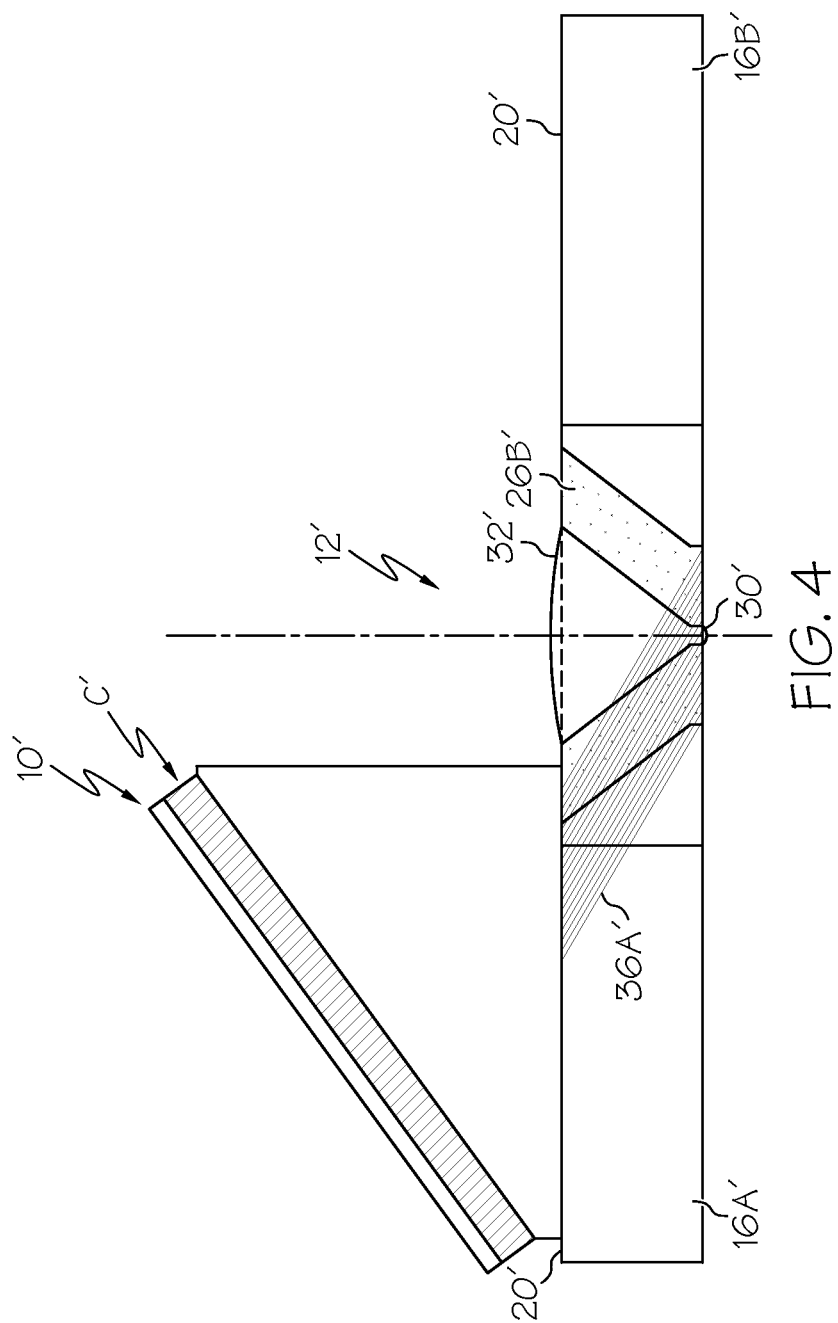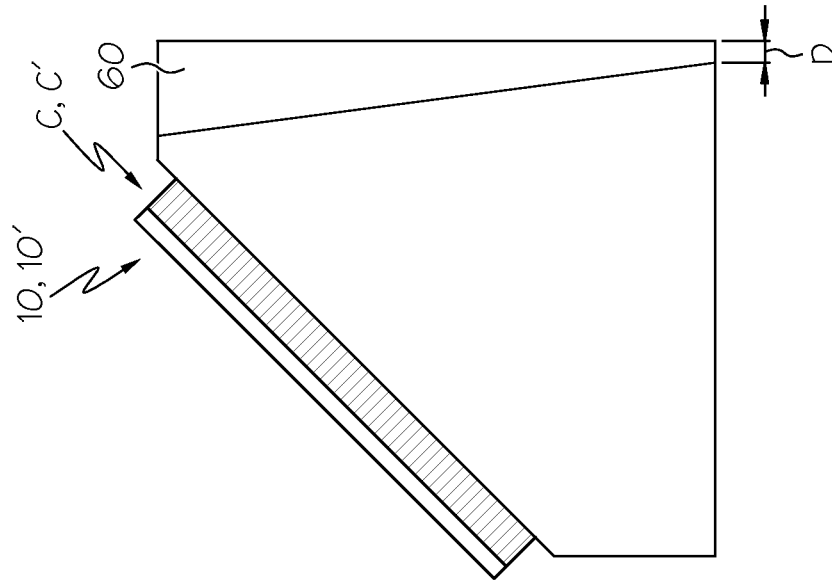
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FIG. 1
(PRIOR ART)

110'

C's

12'

32'

30'

16A'

FIG. 2
(PRIOR ART)

FIG. 3

FIG. 4

FIG. 6

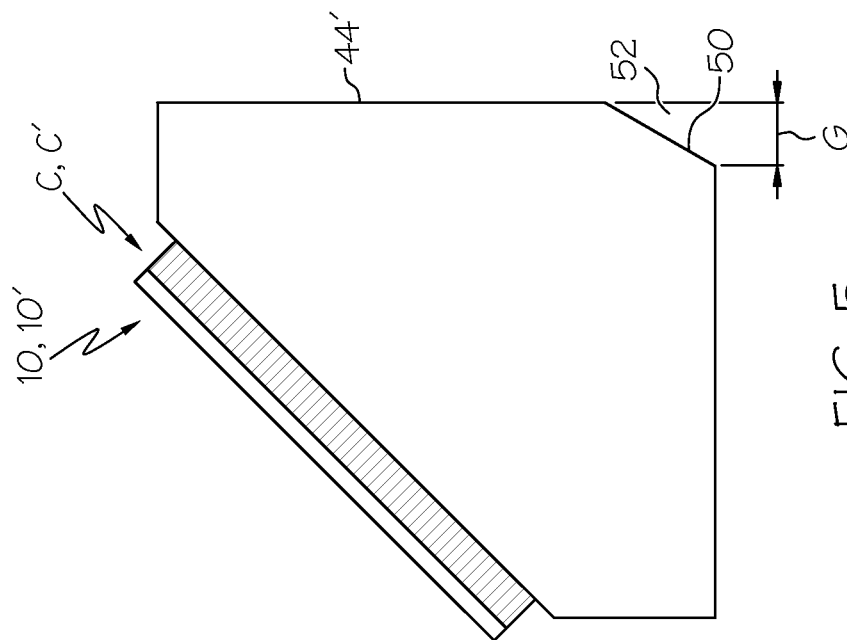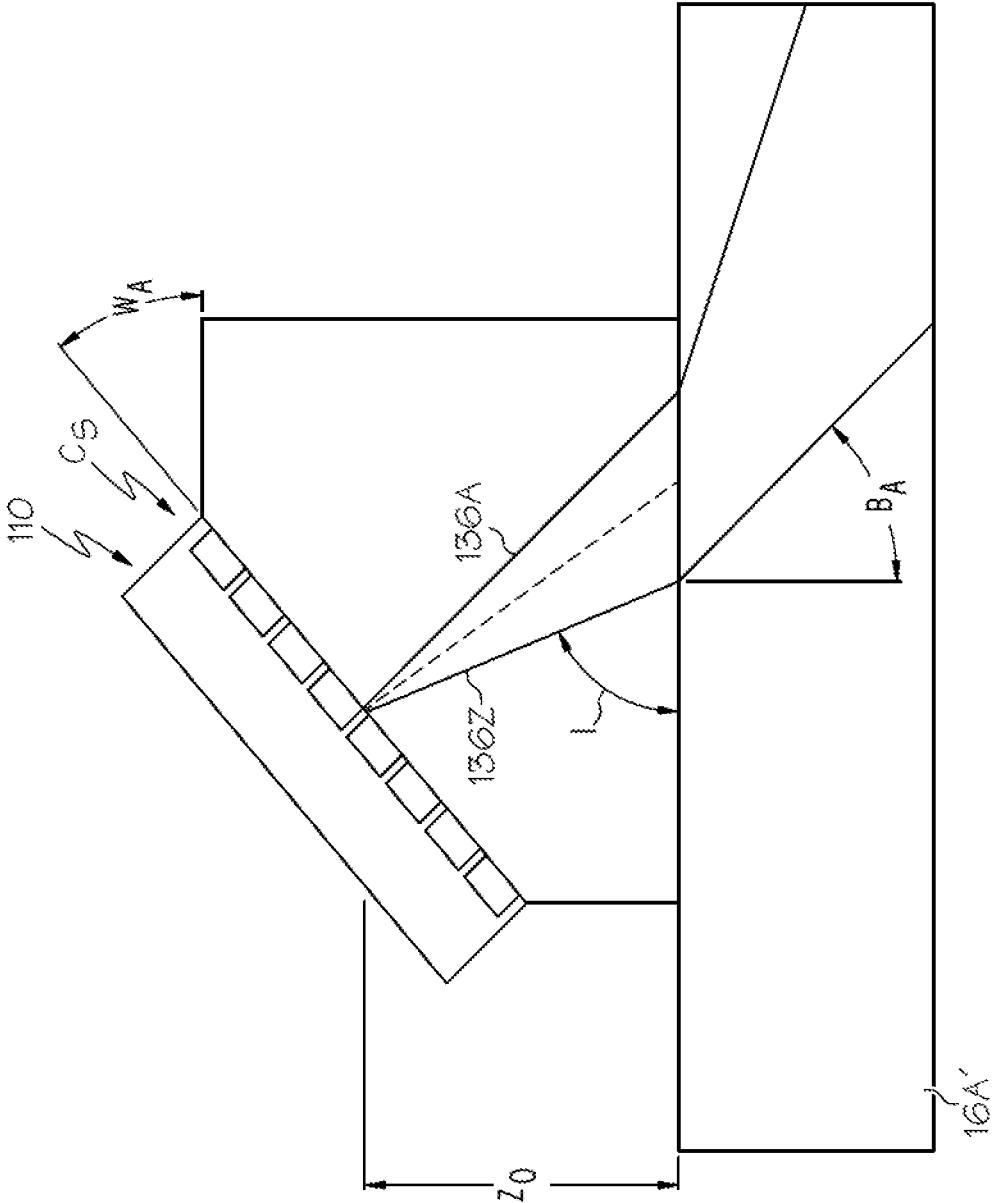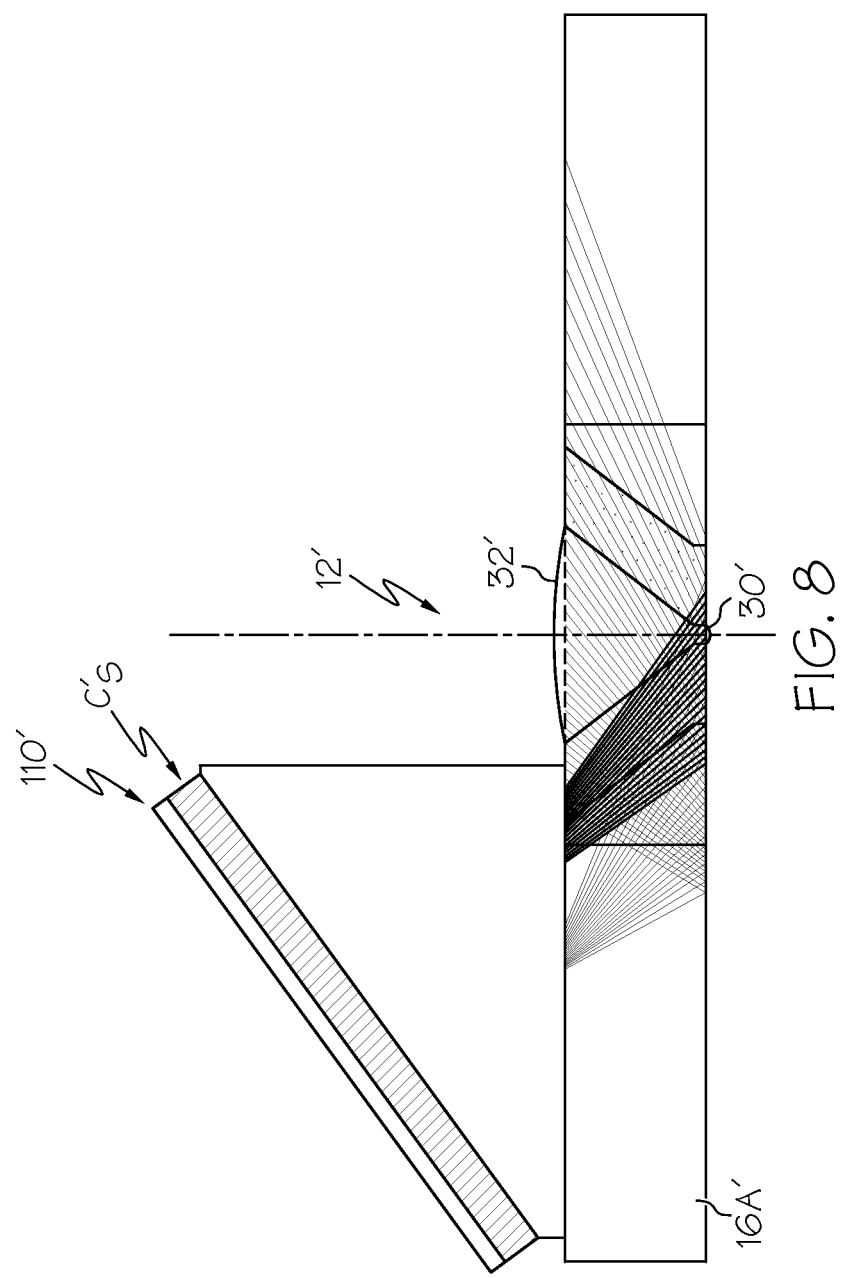*FIG. 5*

FIG. 7

110'

C'S

12'

32'

30'

16A'

FIG. 8

AUTO BEAM OPTIMIZATION FOR PHASED ARRAY WELD INSPECTION

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention relates to ultrasonic inspection of welds, and specifically relates to improved efficiency for completing inspection with an ultrasonic probe having an array of multiple ultrasonic elements.

2. Discussion of Prior Art

Ultrasonic probes are often used to inspect a weld that connects two portions (e.g., sheet members or pipe/conduit sections). Each ultrasonic probe can include a plurality of transducer elements. Each transducer element is capable of emitting a signal that proceeds though the one of the connected portions and into the weld itself. The probe includes a wedge so that the plurality of transducer elements are arranged in an array along the wedge, with each element being at a different location. The difference of location of each transducer element within the array extending along the wedge provides for an associated difference of possible area to which each transducer element will direct its respective signal.

Operation of a probe in order to inspect a weld is often referred to as a scan. In order to perform a scan, the probe is placed upon one of the connected portions at a moderate distance from the weld. The probe is operated (e.g., transducer signals emitted) and the probe is moved along the connected portion relative to the weld.

In order to accomplish useful inspection of a weld, it is common to perform at least two scans on each side of weld. Specifically, two scans on each side help provide for effective scan coverage of the weld. Both a root of the weld and a cap of the weld should receive effective scanning.

As mentioned, different transducer elements within the array can provide for different area sensing. As such, it is certainly possible that one or more transducer elements can be used to accomplish scanning of the weld root and one or more, different transducer elements can be used to accomplish scanning of the weld cap. In general, the weld root and the weld cap are in an area of interest to be scanned. However, it is possible that one or more of the transducer elements are not usable/needed to accomplish scanning of either the weld root or the weld cap (e.g., not within the area of interest). For example, it is possible for one or more certain beams not to pass through either the weld root area or the weld cap area. Perhaps the beams do not even pass near to either the weld root area or the weld cap area (e.g., not within the area of interest).

Turning briefly to FIG. 1, a previously known (e.g., prior) method/approach of operating all of the transducer elements of a linear is schematically shown via FIG. 1. If the particular task is to investigate/analyze a weld root 30', it can be appreciated that some (e.g., a majority in this case) of the transducer beams 36' will not provide useful data. Turning briefly to FIG. 2, another previously known (e.g., prior) method/approach of operating the transducer elements is schematically shown via FIG. 2. FIG. 2 presents an example of a sector-type probe 110' with multiple beams from two transducer elements simultaneously presented. It should be noted that the particular transducer elements/beams do not provide for efficient/effective coverage of the weld area. For example, it should be noted that a large portion of the beams do not enter an Area of Interest in a useful manner.

It is to be appreciated that operation of each transducer element requires a least some amount of energy and time. In

addition, it is to be appreciated that processing of data obtained as a result of operation of each transducer element requires a least some amount of energy and time. As such, increased efficiency or energy and/or time can be obtained via operation of less than all of the transducer elements. However, it should further be appreciated that proper analysis requires that the one or more transducer elements needed to accomplish scanning of the weld root and the one or more, different transducer elements needed to accomplish scanning of the weld cap should of course be operated. As such, the inventors have determined that there is a need to both improve efficiency, via avoiding unnecessarily transducer element operation/data processing, and to accomplish proper analysis.

BRIEF DESCRIPTION OF THE INVENTION

The following summary presents a simplified summary in order to provide a basic understanding of some aspects of the systems and/or methods discussed herein. This summary is not an extensive overview of the systems and/or methods discussed herein. It is not intended to identify key/critical elements or to delineate the scope of such systems and/or methods. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is presented later.

In accordance with an aspect, the present invention provides a method of computing optimal beam numbers of elements of a phased-array ultrasonic weld inspection arrangement. The arrangement is for inspecting a weld that is within an area of interest that has a known dimension and with the inspection arrangement being at a known offset distance from the weld. The selection is such that operation of the at least one element provides sufficient information data for weld analysis. The elements extend along an ultrasonic transmission wedge of the arrangement that supports the extent of the elements at a wedge angle relative to the welded material. The method includes utilizing the dimension of the weld area of interest and dimension of offset of the inspection arrangement from the weld within calculation that yields the selection of the at least one element.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other aspects of the invention will become apparent to those skilled in the art to which the invention relates upon reading the following description with reference to the accompanying drawings, in which:

FIG. 1 is a schematic illustration that shows a prior art approach of operating more transducer elements than necessary to obtain analysis of a root portion of a weld within an area of interest;

FIG. 2 is another schematic illustration that shows another prior art approach of operating more transducer elements than necessary to obtain analysis of a root portion of the weld and a cap portion of the weld within an area of interest;

FIG. 3 is a schematic illustration of an example ultrasonic probe located upon two portions of material connected by a weld and shows the emittance of signals into a connected portion/weld, with selection of at least one element for selective signal emittance being able to improve efficiency in accordance with an aspect of the present invention;

FIG. 4 is a schematic illustration similar to FIG. 1, but shows an approach of operating only transducer elements than necessary to obtain analysis of the root portion of the weld within the area of interest for efficiency;

FIG. 5 is a schematic illustration of a modified wedge usable within the probe of FIG. 3;

FIG. **6** is a schematic illustration of another modified wedge usable within the probe of FIG. **3**;

FIG. **7** is a schematic illustration showing another example ultrasonic probe located upon a portion of material connected by a weld, with the probe providing sectorial scanning; and

FIG. **8** is a schematic illustration similar to FIG. **2**, but shows an approach of operating only transducer elements than necessary to obtain analysis of the root portion of the weld and a cap portion of the weld within an area of interest.

DETAILED DESCRIPTION OF THE INVENTION

Illustrative embodiments that incorporate one or more aspects of the invention are described and illustrated in the drawings. These illustrated examples are not intended to be overall limitations on the invention. For example, one or more aspects of the invention can be utilized in other embodiments. Moreover, certain terminology is used herein for convenience only and is not to be taken as a limitation on the invention. Still further, in the drawings, the same reference numerals are employed for designating the same elements.

An ultrasonic probe **10** is used to inspect an example weld **12** that connects two example portions **16A**, **16B** of material. It is to be appreciated that the connected portions **16A**, **16B** need not be a specific limitation upon the present invention. As such, the connected portions can be varied. Some examples of connected portions include sheet members or pipe/conduit sections. The two connected portions **16A**, **16B** of material can also be varied. Typical examples of the material of the connected portions **16A**, **16B** include various metals and may include ferrous-based metals, aluminum-based material, or the like. Each connected portion (e.g., **16A**, **16B**) includes a proximal (e.g., upper as viewed in the Figures) surface **20** and a distal (e.g., lower as viewed in the Figures) surface **22**. In the shown example, the two connected portions **16A**, **16B**, and thus the surfaces **20**, **22** are planar. However, it is to be appreciated that some curvature may be present.

The weld **12** that connects the two connected portions **16A**, **16B** fixes the two portions together and has been previously been completed (i.e., the weld is solidified). The weld **12** may have varied characteristics that need not be specific limitations upon the present invention. For example, the weld **12** may have varied shape and material characteristics concerning composite material(s). The composite materials may be dependent upon the material of the connected portions **16A**, **16B**. As such, the weld material may include a metal composition, including a ferrous-based or aluminum-based materials or the like.

The weld **12** extends along adjacent edges **24A**, **24B** of the connected portions **16A**, **16B**. Within the Figures, the weld **12** extends transverse (e.g., perpendicular) into and out of the plane of the drawing sheet. As such, the Figures show the weld **12** in cross-section. Thus, the weld **12** has a length (i.e., extends perpendicular away from the plane of the drawing sheet) and can be termed to be a weld line. During the creation process (i.e., the welding process) of the example weld **12** shown within the Figures, weld material is deposited. In addition, some of the material **26A**, **26B** of the connected portions **16A**, **16B** is altered by the application of heat during the weld creation process. Such altering may include melt or partial melt. This area can be referred to as the heat-affected area. As such, the example weld includes a weld root **30** located adjacent to the distal side **22** of the connected portions **16A**, **16B** and a weld cap **32** located adjacent to the proximal side **20** of the connected portions.

It should be noted that the connected portions **16A**, **16B** and the weld **12**, as they appear within the drawings, are in

cross-section. However, it should further be noted that the typical cross-section hatching of the connected portions **16A**, **16B** and the weld **12** are omitted for clarity since numerous lines representing beams, paths, dimensions, etc. (described below) are shown within the drawings to illustrate aspects of the invention.

It is typical that welds (e.g., weld **12**) have an acceptable level of structural integrity and the like. As such, in accordance with one aspect of the present invention, the ultrasonic probe **10** is used to inspect the weld **12**. Specifically, in the shown example, the probe **10** is operated during inspection of the weld **12** as the probe is moved relative to the weld (i.e., at a spaced distance from the weld line and substantially parallel to the weld line direction). Such operation is often referred to as a scan. In order to perform a scan, the probe **10** is placed upon one (e.g., **16A**) of the connected portions **16A**, **16B** at a moderate distance from the weld **12**. The probe **10** is operated and the probe is moved parallel to the connected portion relative to the weld **12**.

In order to accomplish useful inspection of a weld **12**, it is common to perform at least two scans, one on each side of weld **12**. Specifically, two scans on the two sides help provide for effective scan coverage of the weld **12**.

Turning to the details of the probe **10**, the ultrasonic probe includes a plurality of ultrasonic transducer elements C in a linear matrix array. It is to be appreciated that FIG. **3** simply shows an example number of transducer elements C to convey the concept of a plurality of elements C and the shown number is not to be construed as a limitation. In addition, the specific details of the plurality of transducer elements C may be varied. For example, the plurality of transducer elements C may be appropriately connected to a power source, connected to data processing components, etc. Also, the physical construction concerning the transducer elements (e.g., extent/spacing of the plurality of transducer elements) can be varied and thus need not be specific limitations upon the present invention.

Each transducer element C is capable of emitting an ultrasonic signal (e.g., an ultrasonic beam) **36** (several example beams in are shown in FIG. **3**, which are not intended to present a limitation upon the present invention) that can proceed though the material of the connected portions **16A**, **16B** and the material of the weld **12**. The signal can be reflected (echoed) back toward the transducer elements of the probe by various surface interfaces and by characteristic of the weld including defects (e.g., imperfections, deformities, voids, impurities, and the like) that provide surface interfaces.

The reflected signals can be analyzed in order to make determinations about the weld. The reflected signal data analysis can be accomplished via various techniques and as such the analysis need not be a specific limitation upon the present invention. Operation of such a probe **10**, including the powering/operation of transducer elements C, and processing of signals/data derived from the transducer elements are known and can be varied. In addition, various components/devices can be operatively connected to the probe to receive/process the signals/data derived from the transducer elements to determine various characteristics of the weld including defects (e.g., imperfections, deformities, voids, impurities, and the like). Such components/devices and such reception/processing are known and can be varied. Accordingly, such specifics need not be limitations upon the present invention.

Turning to the specific structure of the example probe **10**, the ultrasonic transducer elements C are arranged in a linear array. As a reference, the linear array extends transverse (e.g., perpendicular) to the extent of the weld **12**. Recall that the weld **12** extends perpendicular to the plane of the drawing

sheet (e.g., into and out from the sheet). As such, the linear array extends within in the plane of the drawing sheet.

The probe **10** includes a wedge **40**. The wedge **40** is made of ultrasonic transmissive material. The wedge **40** has a first side **42** for placement against the proximate surface **20** of one of the connected portions (e.g., **16A**). As mentioned, the shown example connected portions (**16A, 16B**) are flat and as such the first side **42** of the wedge **40** has a complementary substantially flat face to mate against the flat of the connected portion **16A**. A different contour of the connected portions can be accommodated via a complementary contour at the first side **42**. A second side **44** in the shown example is perpendicular to the first side **42** and is also substantially flat. However it is contemplated that a different configuration is possible. A third side **46** can be referred to as a hypotenuse side and extends at an angle to the first side **42** and thus the flat of the connected portion (e.g., **16A**). The hypotenuse side extends at a wedge angle W_A. It is contemplated that the hypotenuse side **46** need not extend completely to the first and second sides **42, 44** and the shown example presents truncations so that the hypotenuse side **46** does not extend completely to the first and second sides.

The array of transducer elements C is located on the hypotenuse side **46** of the wedge **40** such that the array extends vertically up at an angle and away from the connected portion (e.g., **16A**) as the array laterally extends toward the weld **12**. As such, the plurality of transducer elements C are arranged in the array along the wedge **40**, with each element being at a different location. The difference of location of each transducer element C within the array extending along the wedge **40** provides for an associated difference of possible area to which each transducer element will direct its respective signal (see for example FIG. **3**). Specifically, each of the transducer elements C within the array emits a respective signal that enters the wedge at a different location and thus enters the connected portion (e.g., **16A**) at a different location. As mentioned, some example beam **36** from different transducer elements C are shown within the connected portion **16A** and the weld **12** in FIG. **3**. It is to be appreciated that the beams traveling through the wedge **40** are not shown in FIG. **3** for clarity and also some of the overall possible beams may not be shown. It should be noted that the plural beams (FIG. **3**) within the presented example are directed so at to proceed parallel to each other as they proceed from the array of transducer elements C.

Turning back to the aspect of each beam entering the wedge at a different location and thus entering the connected portion (e.g., **16A**) at a different location, such difference provides for different transducer elements beams **36** to be able to "sense" (e.g., investigate, interrogate, etc.) a different location, including possibly different locations that may or may not contain the weld and specifically to different locations that may contain different portions of the weld. An ability to effectively and efficiently scan and analyze all portions of the weld (i.e., including the weld root **30** and the weld cap **32**) is beneficial. So logically, different transducer elements C and associated different beams **36** can be employed to accomplish this beneficial function. It should also be noted that merely utilizing all transducer elements/beams is somewhat inefficient since some beams will not travel through any portion of the weld area at all and thus do not have an ability to detect/provide information about the weld/weld area.

In general, the area that needs to be investigated/analyzed is the weld itself and at least some minimum surrounding area which includes the heat-affected areas (e.g., melt/partial melt) of the connected portions **16A, 16B**. As a corollary, at least some, and likely most (e.g., a bulk), of the connected

portions **16A, 16B** need not be investigated/analyzed. The area that needs to be investigated/analyzed (i.e., the weld and some surrounding area) is referred to as the Area of Interest (identified as AOI within FIG. **3**). The size of the Area of Interest that needs to be investigated/analyzed can be dependent upon several factors such as weld size, weld type, thickness of the connected portions **16A, 16B**.

Operating/utilizing only some of the transducer elements C to provide the needed investigation/analysis of such an area provides efficiencies, such as cost efficiencies and time efficiencies. Specifically, operation of transducer elements C and processing of data from transducer elements requires both energy and time. A reduction of the number of transducer elements C operated and/or amount/volume of data processed provides savings. However, it should be appreciated that a minimum, and correctly located, amount of transducer elements C should be operated, and data therefrom processed, to effectively scan the weld.

Focusing again upon FIG. **3**, it should be noted that within the shown example, only some beams **36** from the transducer elements C are shown. It is to be appreciated that the shown transducer beams **36** need not be all of the possible transducer beams that may be output from the array of transducer elements C. The shown transducer beams **36** are simply a representative portion to help illustrate an aspect of the present invention.

The shown transducer beams **36** proceed within the connected portion (e.g., **16A**) along two legs L1, L2 (with each leg extending between the surfaces **20, 22** and terminating at reflection). However, a first sub-set of the transducer beams **36A** proceeds into the area of interest (AOI), while a second subset of beams **36B** does not so proceed into the area of interest. The first subset of beams **36A** will likely provide useful data concerning weld investigation/analysis, whereas the second subset of beams **36B** will likely not provide useful data concerning weld investigation/analysis. Thus, in accordance with an aspect of the present invention, the beams of the second subset **36B** can be segregated out so that the associated transducer elements are not so operated and/or data that would be associated with the beams of the second subset would not be processed. This, segregation to reduce or lower the amount of transducer element operation and/or associated data analysis is easily appreciated via a comparison of FIGS. **2** and **3**.

Turning to a comparison of FIGS. **1** and **4**, it is to be appreciated that similar reference numerals are used to represent similar structures/features, but with a prime (') added in FIG. **1**. Before proceeding to further discussion about FIGS. **1** and **4**, it should be appreciated that, as compared to FIG. **3**, FIGS. **1** and **4** also show a slightly different probe **10'**, slightly different connected portions and weld **16A', 16B', 12'** and a slightly different relative positioning of the probe to the weld. These slight variations are to emphasize that difference are possible.

Proceeding now with the comparison, recall that the previous approach shown FIG. **1** presents the aspect that some (e.g., a majority in this case) of the transducer beams **36'** will not provide useful data. In distinction, turning to FIG. **4**, a group (identified as **36A'**) selected in accordance with an aspect of the present invention provides useful data about the weld root **30'**. The present invention includes the aspect of calculating the number of beams that will proceed to a particular area (e.g., the area of interest or a specific portion of the area of interest). As a corollary, the present invention includes the aspect of calculating the number of beams that will not proceed to the particular area (e.g., the area of interest or a specific portion of the area of interest).

The calculation can take into account many features and variables of the probe (e.g., **10** or **10'**) being utilized. For example, the probe may have a wedge that includes a "clipped" leading edge **50** (see FIG. **5**). Specifically, a corner of the wedge that is adjacent to the surface **20** and closest to the weld **12** is removed to provide for an open or "clipped-away" area **52**. Such a clipped leading edge **50** can provide for position of the probe at a relatively close proximity to the weld (e.g., immediately adjacent) while avoiding adverse contact with raised portions (e.g., the weld crown). However, such a clipped leading edge **50** does provide a front gap has a horizontal distance G through which transducer beams do not travel. As another possible example feature, the transducer may have a wedge that include a front material segment **60** made of a different material that damps ultrasonic beams from proceeding there through. See FIG. **6**. Such a material segment **60** can be used for controlling ultrasound beam reflection. Such a front material segment **60** can have a distance D.

As still further features of the probe that can be taken into account in order to determine/select the sub-set group transducer elements/associated beams to accomplish the investigation/analysis, the probe may be a scanning-type probe **110** (FIG. **7**). The scanning-type probe can also be referred to as a sector-type. FIG. **7** shows an example range within which a particular sector-type transducer element C_s can direct its beam. Specifically with FIG. **7**, the dash line proceeding from the particular transducer element C_s indicated a normal (i.e., perpendicular) direction from transducer element. The beam path indicated by reference numeral **136A** indicates a first example beam path along a furthest reach of the scan. The beam path indicated by **136Z** indicates an example last beam path along a furthest reach of the scan. As can be appreciated, the two furthest reaching beam paths **136A**, **136Z** have different entry points into the connected portion **16A** and that as the beam moves or scans between these two furthest reaching beam paths, **136A**, **136Z**, the beam will have an ever-changing path. In addition, as can be appreciated upon viewing FIG. **7**, the path of the beam through the connected portion **16A** will thus vary. Still further, similar variations of beam paths will occur for the other beams from the other transducer elements of the sector-type probe **110**.

Turning to a comparison of FIGS. **2** and **8**, it is to be appreciated that similar reference numerals are used to represent similar structures/features, but with a prime (') added in FIG. **2**. Within FIG. **2**, the particular transducer elements/beams do not provide for efficient/effective coverage of the weld area. For example, it should be noted that a large portion of the beams do not enter the Area of Interest in a useful manner. FIG. **8** provides an example in accordance with an aspect of the present invention and presents beams from two transducer elements that efficient/effective coverage of the weld area. Note that the beams of one transducer element are efficiently/effectively providing coverage for the weld root **30'** and that the beams from another transducer element are efficiently/effectively providing coverage for the weld cap **32'**.

As mentioned, different transducer elements can provide for different area sensing. As such, in accordance with an aspect of the present invention, it possible that one transducer element, or smaller group of transducer elements, can be used to accomplish scanning of the weld root and another transducer element, or smaller group of transducer elements, can be used to accomplish scanning of the weld cap. As another aspect of increased efficiency the other/remaining transducer elements that may not provide for desired scanning can idled or otherwise omitted from operation. However, because it

may not be initially known which transducer element(s) will properly accomplish thus an aspect of the present invention is to make determinations of such.

Selection of transducer elements of the array to utilize/not utilize is provided by a process in accordance with the present invention. One example series of algorithms is provided to do such a process. It is to be appreciated that other algorithms are possible and are to be considered to be within the scope of the present invention.

In general, it is to be appreciated that one example process is presented herein. It is to be appreciated that the process may be varied and that other, different processes can also be utilized. It is to be appreciated that such variations and differences are contemplated to be within the scope of the present invention. As such, the present example is not to be considered a limitation boundary of the present invention. For ease of understanding the following nomenclature is presented. It is to be appreciated that the nomenclature can also be varied without departing from the present invention.

Nomenclature:

$N0$=Total number of transducer elements within the array of the probe

Part Entry Point=(For sector type only) Is the entry point at the furthest beam

Nominal Point=(For sector type only) Is the point at which the beam will enter the connected portion as it would proceed in a nominal (e.g., perpendicular to transducer element array)

I=incidence angle

WA=Wedge angle, which is the angle between the upper surface of the connected portion (i.e., the be welded portion) and the array of transducers as defined by the wedge interposed there between

BA=Beam Angle as the beam enters the connected portion

Z_0=Vertical wedge offset, which is the vertical distance of the Probe element from the welded material

X_0=Horizontal wedge offset, which is the horizontal distance of the center element from the edge of the wedge closest to the weld

VW=Wedge Velocity, which is the known velocity of the ultrasonic beam within the wedge

VS=Material Velocity, which is the known velocity of the ultrasonic beam within the material of the connected portion

TZ=Material Thickness, which is the vertical thickness of the connected portion that is welded

Leg=Number of times beam bounce/reflect inside the connected portions

Pitch=Center to center distance between two adjacent probe elements

HAZ=Parent metal, horizontal width of heat affected zone on parent metal. That is heat transferred from molten metal on weld preparation

$XLIMIT$=one half of the width of the weld cap (Overcap-Width/2)

PPL=ProbePositionLeft, is the horizontal offset from a weld centerline to the edge of the wedge

$INDEXSTART$=is the horizontal dimension from the outer edge of the HAZ (Disturbed parent metal) to the edge of the Area of Interest (AOI) at the near side of the weld

$INDEXSTOP$=is the horizontal dimension from the outer edge of the HAZ (Disturbed parent metal) to the edge of the Area of Interest (AOI) at the far side of the weld

Steps of the example process:

Beam Coordinates Calculation

This calculation is to derive the values of probe exit point and part entry point in terms of horizontal and depth axes. The

coordinates will vary for each beam based on its angle of refraction. Hence the given below formula for any beam angle. Substitute the appropriate beam angle and other parameters to get the correct value.

Part Entry Point Calculation:

Part Entry Point Depth=0 mm

Part Entry Point Horizontal has to be computed in four steps.

Step 1: Calculation of Nominal Entry Point

Nominal Point in $mm = Z_0 * \mathrm{Tan}(W_A)$

Step 2: Calculation on incidence angle (I)

Incidence Angle (in degrees)=arcsine [sin(Highest Beam Angle)*(V_W/V_S)]

Step 3: Calculation of Beam Entry Point

Beam Entry Point in $mm = Z_0 * \mathrm{Tan}$ (Incidence Angle)

Step 4: Calculation of Part Entry Point Horizontal

Part Entry Point Horizontal=Beam Entry Point–Nominal Point

Probe Exit Point Calculation

Probe Exit Point Depth=–[Wedge Offset Z]

Probe Exit Point Horizontal=–[(Wedge Offset Z)*tan (Wedge Angle))]

Beam coordinates are based upon the Part Entry Point Depth and the Part Entry Point Horizontal.

It is to be appreciated that the above calculations is specific to sector-type and linear scan-type need not utilize all of the above calculations. The overall calculation process can thus proceed, with an understanding that dependent upon scan type, etc. some parameter/calculation steps are moot.

Thus proceeding with the calculation:

clsPass.StartAngle=clsPass.SectorScanAngleStart (which is used to set an angle value);

IList<BeamCoordinates>beamCoordinates=Beam Coordinates.GetBeamCoordinates(clsPass, X_0, W_A, BA, V_w, T_Z, N_0, Pitch);

int noOfBeamsOutOfAOI=0 (the process is initiated with a presumption that none of the beams are outside of the Area of Interest);

double BA=0;

for int i=0; i<beamCoordinates.Count; i++(for sequencing through the various available beams, either just a linear array sequence or with the angle steps of associated with sectorial scanning)

if clsPass.PassDefinitionMethod=PassDefinitionMethod. MultipleSectorialScans (for sectorial scanning)

if (i=0), then BA=clsPass.SectorScanAngleStart

else, BA=BA+clsPass.SectorScanAngleStep

else if clsPass.PassDefinitionMethod=PassDefinitionMethod. MultipleLinearScans (for linear scanning)

BA=clsPass.LinearScanBeamAngle

if clsPass.PassType=InspectionPassType.Left_Cap||clsPass. PassType=InspectionPassType.Left_LowerCap||clsPass. PassType=InspectionPassType.Left_Root||clsPass.Pass Type=InspectionPassType.Left_Single (for a pass that is from the left for any of the weld types)

double Length1=clsPass.PPL+X_0–INDEXSTART– XLIMIT–HAZ–Z_0*TanOfDegrees(WA) (a calculation for Length 1)

double Length2=clsPass.Leg*T_z*TanOfDegrees(BA)+ beamCoordinates[i].PartEntryPointHorizontal (a calculation for Length 2)

if (Length2<Length1), then Beam is of AOF, add to noOfBeamsOutOfAOF else if (clsPass.PassType=InspectionPassType.Right_Cap||cls Pass.PassType=InspectionPassType.Right_Lower Cap||clsPass.PassType=InspectionPassType.Right_ Root||clsPass.PassType=InspectionPassType.Right_ Single (for a pass that is from the left for any of the weld types)

double Length1=clsPass.ProbePositionRight+ Wedge.OffsetX–INDEXSTOP–XLIMIT–HAZ– Z_0*TanOfDegrees(WA) (a calculation for Length 1)

double Length2=clsPass.Leg*T_Z*TanOfDegrees(BA)+ beamCoordinates[i].PartEntryPointHorizontal (a calculation for Length 2)

if (Length2<Length1), then Beam is of AOI, add to noOfBeamsOutOfAOI;

return noOfBeamsOutOfAOI (which returns an indication of the number of beams that are outside of the area of interest and thus indicates the transducer elements for which operation can be omitted for efficiency).

Thus, the technical effect is to provide a method of determining the transducer elements for which operation can be omitted for efficiency. Examples of omitted operations include: (1) not operating some of the transducer elements so that beams are not even emitted and (2) not utilizing data obtained from some of the transducer elements. Omission of such operations provides savings in operation costs and operation time. It is to be appreciated that the process in accordance with the present can be performed via the aid of a calculation device and/or a computer. Of course, in a most basic form, the process can be performed without the aid of such devices. However, use of such devices would itself provide for improved efficiency.

An example of the invention has been described with reference to the example embodiments described above. Modifications and alterations will occur to others upon a reading and understanding of this specification. Example embodiments incorporating one or more aspects of the invention are intended to include all such modifications and alterations insofar as they come within the scope of the appended claims.

What is claimed:

1. A method of computing optimal beam numbers of a phased-array ultrasonic weld inspection arrangement inspecting a weld that is within an area of interest that has a known dimension and with the inspection arrangement being at a known offset distance from the weld, such that operation of the at least one element provides sufficient information data for weld analysis, wherein the elements extend along an ultrasonic transmission wedge of the arrangement that supports the extent of the elements at a wedge angle relative to the welded material; the method including:

utilizing the dimension of the weld area of interest and dimension of offset of the inspection arrangement from the weld within calculation that yields the selection of the at least one element.

2. A method as set forth within claim 1, wherein the calculation includes iterations of successive calculation steps, with each step determining whether a successive element should be included within the selection of the at least one element that provides sufficient information data for weld analysis.

3. A method as set forth within claim 1, wherein the selection of the at least one element includes selection of plural elements.

4. A method as set forth within claim **3**, wherein the weld includes a weld root and a weld cap, the selection of the at least one element includes selection of at least one element that provides sufficient information data for weld root analysis and selection of at least one different element that provides sufficient information data for weld cap analysis.

5. A method as set forth within claim **1**, wherein the method is utilized with an inspection arrangement that has an array of linear scan elements.

6. A method as set forth within claim **1**, wherein the method is utilized with an inspection arrangement that has an array of sector scan element.

7. A method as set forth within claim **1**, wherein the elements extend along an ultrasonic transmission wedge of the arrangement that supports the extent of the elements at a wedge angle relative to the welded material, and the method includes utilizing the wedge angle within the calculation that yields the selection of the at least one element.

8. A method as set forth within claim **1**, wherein the calculation includes utilizing the dimension of a cap of the weld.

9. A method as set forth within claim **1**, wherein the calculation includes utilizing the dimension of welded material that has been heat affected by the weld.

10. A method as set forth within claim **1**, wherein the calculation includes utilizing an angle that the beam proceeds into welded material.

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